Satellite Stereo Images for Risk Monitoring

Caprioli M.*, Scarano A.*, Trizzino R.**

* Politecnico di Bari, DICATECh, Bari, Italy
** CNR, IRPI, Bari, Italy

Abstract. Surface monitoring is essential to understand the spatial and temporal evolution of complex landscape modifications and instabilities related to road and railway infrastructures. In recent years, the terrain change detection methods have evolved particularly with the development of increasingly automatic extraction procedures of both DTM and DSM. Prevention of damages caused by natural disasters does not only concern weather forecasts, but requires constant attention and practice of monitoring and controlling human activity on territory. Practically, the problem is not knowing if and when an event will affect a determined area, but recognizing the possible damages if this event happened, by adopting adequate measures to keep them down as far as possible, and requires the necessary tools for a timely intervention. To solve such requirements, current satellite technology, with recurrent data acquisition for the timely generation of cartographic products updated and coherent to the territorial investigation, offers the possibility to fill the temporal gap between the need of urgent information and official reference information. The fundamental merits of the high resolution remote sensing methods are the ability to perform surveys at regular intervals, the characteristics of the image and the revisit times. These features are very useful in environmental monitoring especially in the event of emergency or also in medium scale cartographic production, particularly in the zones of difficult access and in developing countries. The research presented here aims at answer to the growing need of optimization and rationalization of long term monitoring systems of displacements and degradation due to the interaction of artificial artifacts of transport with such natural phenomena. To test the methodology we chose an area that presents a particular geo-morphological setting, in the municipality of Fasano (BR, Southern Italy). The area is affected by frequent hydrogeological dangerous events such as flooding and is classified as a zone of “high hydraulic hazard” in the regional Hydrogeological Structure Plan (PAI). For this area we used a GeoEye-1 stereo-pair for extracting a DTM in order to verify the usefulness of satellite techniques for the recognition of environmental risks.

Keywords: Remote Sensing, Stereo-image, DTM

1. Introduction

The technological development of road and rail infrastructures and their transport carriers in the trans-European transport corridors leads to an increase in their functional vulnerability with respect to differential movements and degradation of the artifacts. They can be caused by the interaction between artifacts and natural phenomena in slow evolution (rates of mm-cm/year), such as slope instability and subsidence, in addition to project faults or/and normal wear/fatigue of the products. Such interaction may determine, for periods of years or decades, the acceleration of degradation up to critical conditions of functionality. This is the reason why it is necessary to analyse and monitor differential slow movements and degradation. The research presented here aims at answer to the growing need of optimization and rationalization of long term monitoring systems of displacements and degradation due to the interaction of artificial artifacts of transport with such natural phenomena. This optimization and rationalization could be performed through the integration and the optimization of different monitoring systems, that work in situ or remotely, the experimentation and strengthening of data integration techniques with the aim of defining the efficiency of measures with respect to the active geological and geo-technic phenomena and the assessment of applicability of long term monitoring.

Finally, the ability to keep an efficient monitoring of infrastructures, foreseeing the most damaging events, increases the economic and social security of the community.

2. Aims of the Study

The communication of the European community regarding the protection of infrastructures (COM/2006/0786) reports that the protection of critical infrastructures –among them, the strategic infrastructures of transport- must be based on a multi-risk approach, considering also natural risks. The research is thus intended to fill a gap in the management process of transport infrastructures, i.e. the lack of codified procedures for the long-term management of monitoring plans and maintenance of such facilities. A proper integration of these techniques, addressed to the multi-platform monitoring may allow optimization of long-term monitoring of transportation infrastructures.

Surface monitoring is essential to understand the spatial and temporal evolution of complex landscape modifications and instabilities related to road and railway infrastructures.

To this end the study presented here aims at answering to the need of rationalization and innovation in methodologies for monitoring long-term displacement and degradation of road and rail transport infrastructure of strategic importance affected by geotechnical and geological processes exhibiting a slow evolution, so to improve the analysis of the problems related to structure-terrain interaction and, consequently, improve prevention of critical conditions that may affect the functional integrity and the safety of transports. To support the long-term management of monitoring and maintenance plans it is necessary to consolidate operational protocols of planning, integration, execution and processing of multi-platform measurements, operated with some of the most innovative terrestrial and satellite technologies available for the monitoring of slow movements and for the qualitative and quantitative evaluation of degradation of infrastructure artifacts. So we tried to develop innovative approaches for the validation of the results of multiplatform monitoring, to analyze systematically the consistency of the results of the monitoring information with respect to the type of infrastructure and the geological and geotechnical problems, with the aim of achieving the objectives sought by potential end users and to encode the scope and the limits of applicability and long-term operational sustainability of the different measurement techniques adopted in order to produce guidelines, particularly directed not to reduce the vehicle flow, as a tangible and verifiable result of the research.

3. The Test Area

To test the methodology we chose an area that presents a particular geomorphological setting, in the municipality of Fasano (BR, Southern Italy). This area is located in the Southeastern margin of the "Altopiano delle Murge", a karst topographic plateau of rectangular shape occupying the central area of the Apulia region (*Figure 1*).

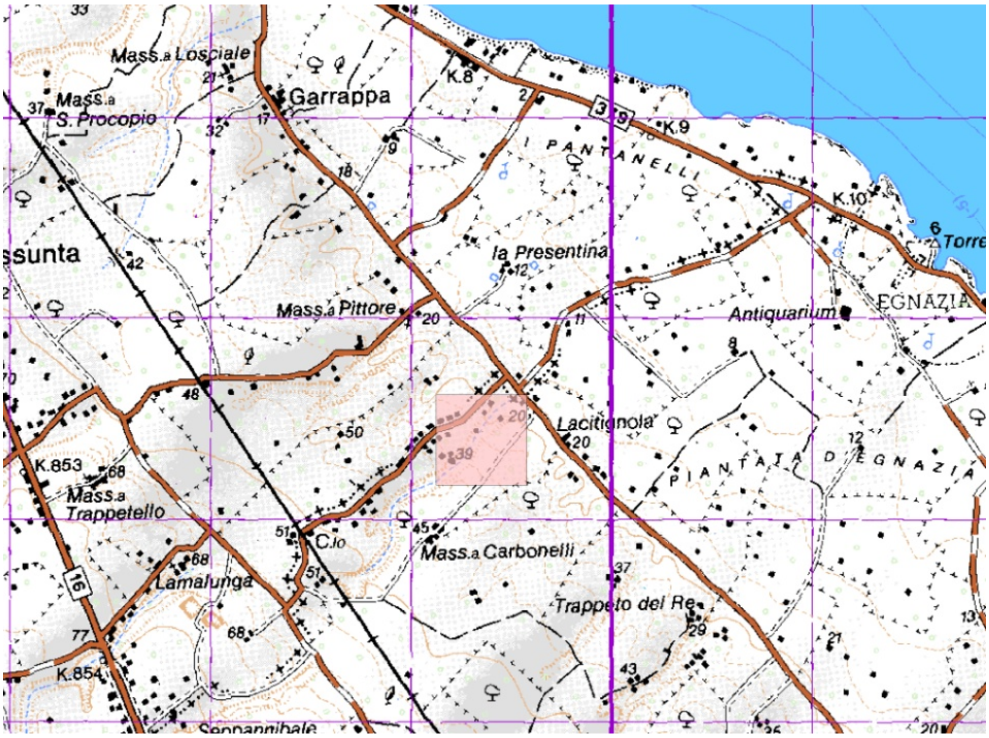

Figure 1. Test area

The highest elevation of the plateau is the Monte Caccia (High Murgia, northern Apulia) at 679 m asl. In the area of Selva di Fasano the elevation of the Lower Murgia is of about 400 m asl. The area is located on the ridge of a “graben” which shows fresh cliffed sides. It is a singular topographic feature very interesting to be investigated.

The Murgia Platform overlooks the Adriatic sea with a characteristic sequence of "steps” gently dipping towards the coast defining a transition zone locally called “coastal selvedge”.

Figure 2. GEOEYE Stereo-image.

Figure 2 shows the GeoEye stereo image of this zone where are clearly recognizable the cliffed sides of the ridge. The GEOEYE METADATA are the following:

Sensor Type: Satellite

Sensor Name: GEOEYE-1

Processing Level: Standard Geometrically Corrected

Image Type: PAN/MSI

Pan Resolution mt.0.50

MSI Resolution mt 1.64

Interpolation Method: Cubic Convolution

Multispectral Algorithm: Projective

Map Projection: Universal Transverse Mercator

Datum: WGS84

File Format: GeoTIFF

Bits per Pixel per Band: 11 bits per pixel

Multispectral Files: RGB File

Spectral range

(pan)	450-800 nm
Blue	450-510 nm
Green	510-580 nm
Red	655-690 nm
Near IR	780-920 nm
Launch date	06-Sep-08
Life Cycle	7 years
Revisit Time	3 days
Orbital Altitude	681 km

In this zone there are many areas classified of "high hydraulic hazard" in the regional Hydrogeological Structure Plan (PAI) of the Puglia region (blue areas in *Figure 3*).

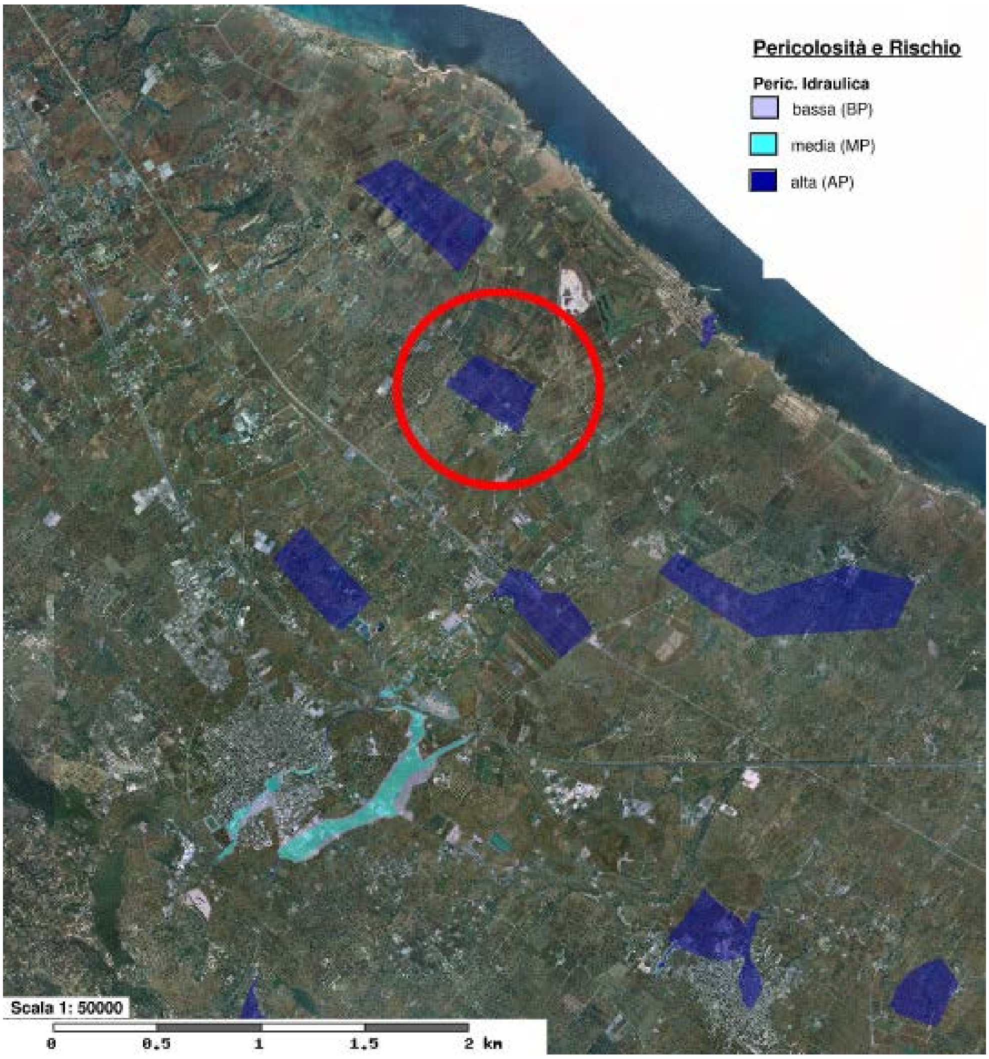

Figure 3. Regione Puglia Hydrogeological Structure Plan (PAI)

As a matter of fact, the municipality of Fasano is crossed by the state road SS16 (*Figure 4*).

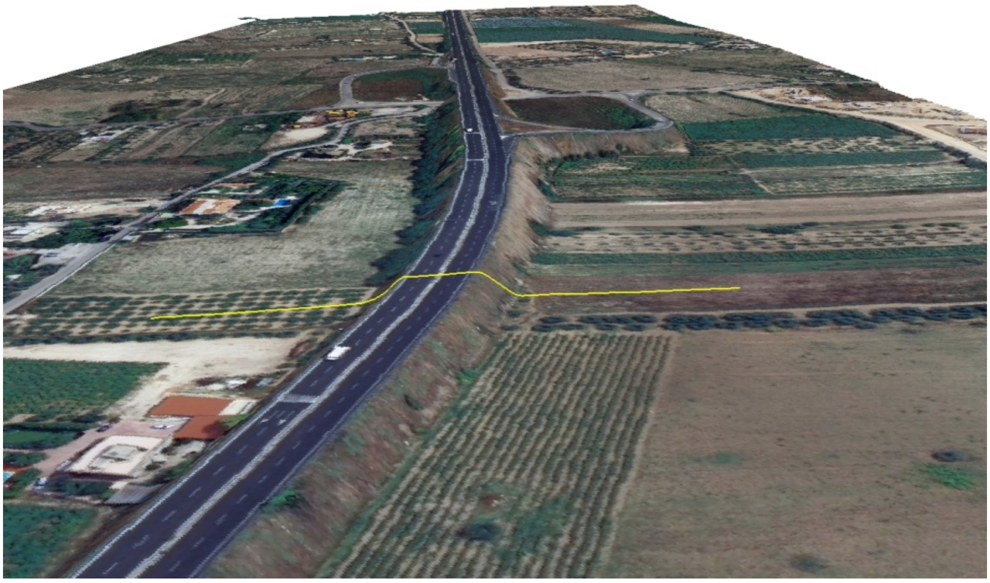

Figure 4. Render of the State Road n. 16 (SS 16).

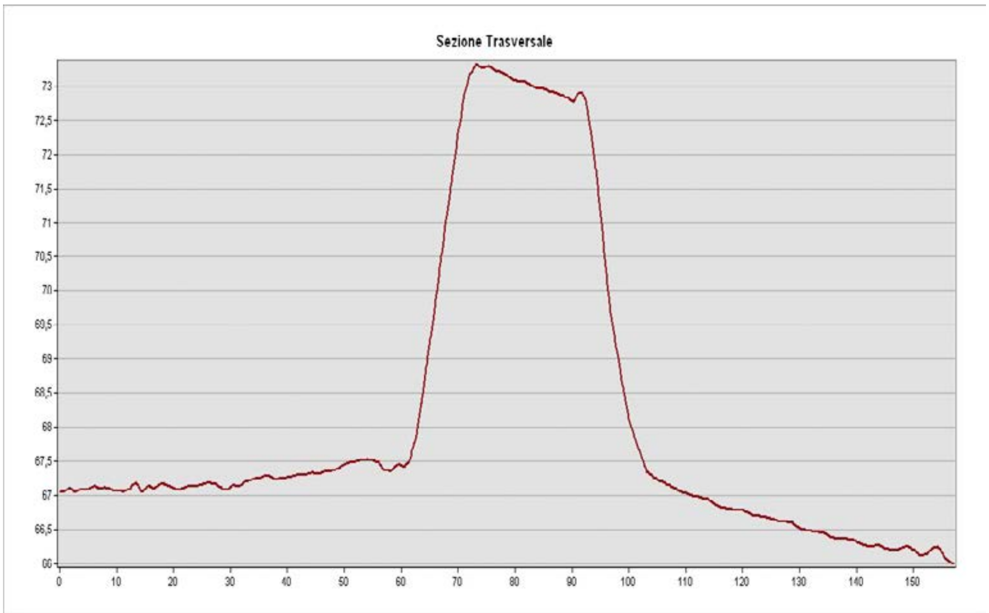

Figure 5. Transversal section of the road.

In various sections the areas crossed by the road are subject to high environmental risk, in particular due to the stagnation of rainwater at the road artefacts (culverts, bridges, etc. ....) in a poor state of maintenance

This circumstance at particularly intense rainfall events can cause flooding in the surrounding areas. This problem is due to the particular morphological setting with High Level differences (400 m – 100 m) in a small distance between the top of hills and the road site.

In such areas the monitoring of changes of the territory is fundamental in order to prevent or reduce the risks for the environment and for the citizen.

The GEOEYE stereo-image has been utilized to obtain a DTM of the risk area just classified in the PAI shown in *Figure 3*.

The following *Figure 6* shows the DTM render obtained from GEOEYE stereo-image where we can see immediately the water collecting valley.

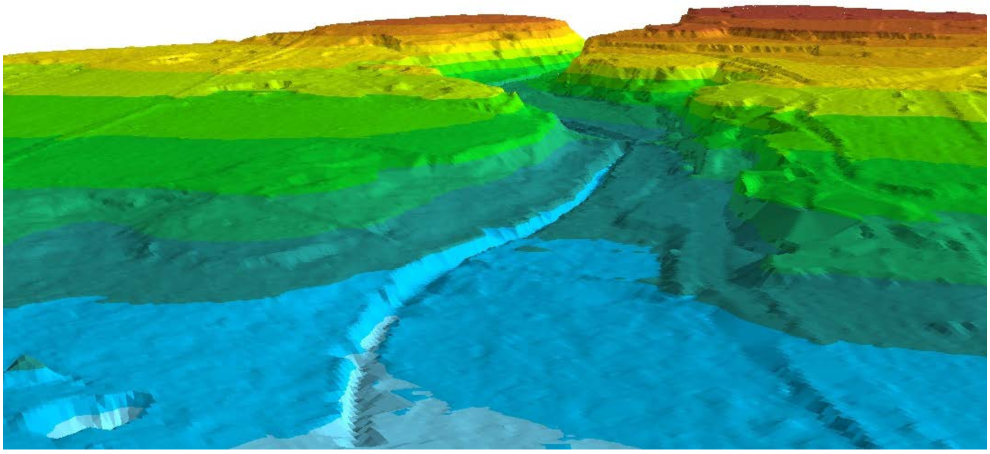

Figure 6. Render of Digital Terrain Model of the valley.

The next *Figure 7* shows a transversal section of the analysed road obtained from the same DTM.

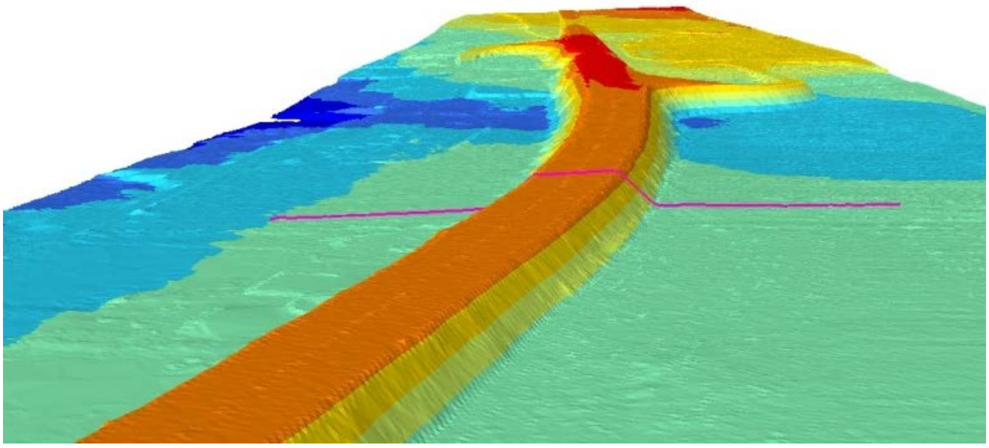

Figure 7. Transversal section in the GEOEYE DTM

4. Conclusion

The availability of GeoEye-1 stereo-image allowed to perform the test reported in this paper. The results encourage the use of satellite stereo-image DEM for the detection of changes, especially in order to know immediately the consequences of natural disasters and to search environmental abuse. This method has been tested on a small area but it can be easily extended to larger areas. The main benefits of using stereo pair are the repeatability and the immediate detection of changes in the area both for natural events and human ones too, that allows early recognition of environmental risk situations, and make it possible to adopt appropriate remediation and early warning measures

References

Baudoin A., Goud P, Rouze M (2001) The Pleiades Program, Joint ISPRS Workshop “High Resolution Mapping from Space 2001”, Hannover

Caprioli M, Scarano A, Scognamiglio A, Trizzino R (2013) Comparative Analysis of satellite stereo images methods and traditional techniques for environmental risk monitoring. ISPRS WG V. Padova

Caprioli M, Scognamiglio A (2012) Change detection methods for multi-emporal analysis of satellite data aimed at environmental risk monitoring. F.I.G. Working Week

Crespi M, Capaldo P, Fratarcangeli F, Nascetti A, Pieralice F (2010) DSM generation from very high optical and radar sensors: problems and potentialities along the road from the 3d geometric modeling to the surface model. Proceedings IGARSS, Honolulu, Hawaii, USA

Crosetto M, Pérez Aragues F (1999) Radargrammetry and SAR interferometry for DEM generation: validation and data fusion. Proceedings of CEOS SAR Workshop, ESA-CNES, Toulouse.

Dial G, Grodecki J (2002) IKONOS Accuracy without Ground Control, Pecora 15 / Land Satellite Information IV / ISPRS Com. I, Denver

Hanley HB, Yamakawa T, Fraser CS (2002) Sensor Orientation for High Resolution Imagery. Pecora 15 / Land Satellite Information IV / ISPRS Com. I, Denver

Jacobsen K (2003) DEM Generation from Satellite Data. EARSeL Conference, Ghent

Li Z, Zhu Q, Gold C (2005) Digital Terrain Modelling: principles and methodology. CRC Press, Florida, USA

Toutin T, Gray L (2000) State-of-the-art of elevation extraction from satellite SAR data. ISPRS Journal of Photo-grammtery & Remote Sensing 55, ELSEVIER :13-33